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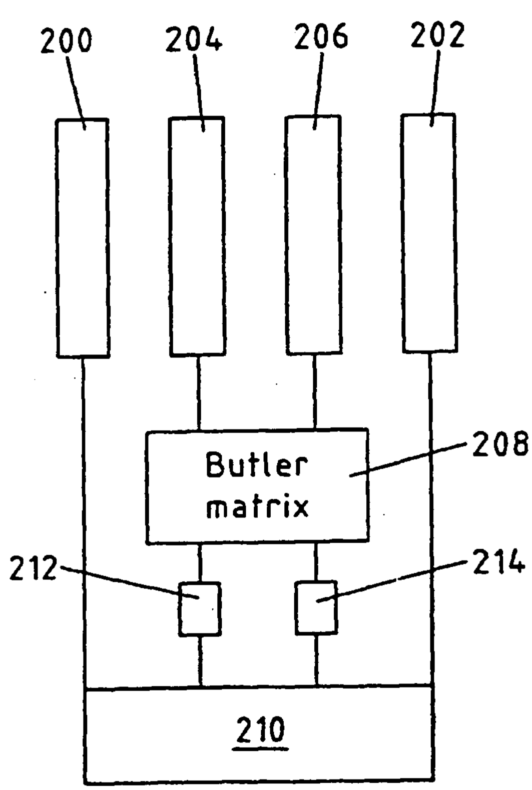
(54) Title: HYBRID ANTENNA ARRAY



(57) Abstract: The invention relates to a base station in a mobile communication network, comprising one antenna array, sending signals bearing dedicated as well as broadcast channels into a sector of interest, beamforming means adjusting phase angle and/or amplitude of one of said signals being applied to the antenna, and a transceiver unit. To provide a base station being capable of sending directed beams as well as undirected beams, whereby the size of the base station is kept small, a base station wherein said antenna array comprises two groups of antenna elements, where one first group of antenna elements transmits at least one undirected beam, bearing at least one broadcast channel that is common for said whole sector, and where one second group of antenna elements transmits at least two directed beams, each beam bearing said dedicated channels that are intended only for a part of said sector is proposed.

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Hybrid antenna array

The invention relates to a base station in a mobile communication network, in particular a cellular mobile communication network comprising at least one antenna array with at least four, parallel arranged antenna elements, sending signals bearing dedicated as well as broadcast channels into a sector of interest beamforming means adjusting phase angle and/or amplitude of at least one of said signals being applied to the antenna elements, and a transceiver unit generating and receiving said signals. The sector of interest may be in the azimuth plane as well as in the vertical plane.

In today´s wireless mobile cellular communication networks, the increase of subscribers forces the operators to use the available bandwidth more efficiently. Known options are allocating more frequency, using frequency-hopping techniques, and adding micro cells into hot spots, where communication traffic is high. All these techniques do not solve the problem of interference between channels of adjacent cells. During frequency planning of the network, it has to be taken into account that adjacent cells must not use the same frequencies. Another known option is the use of adaptive antenna systems. In adaptive antenna systems, a plurality of beams, bearing the channels being transmitted to the mobile stations and being spatially spaced apart are directed into the cell. A beam is a region of high signal strength. It is a matter of feeding an antenna array with

signals being phase angle and/or amplitude shifted against each other that the power of transmitted signals of an antenna array is not homogeneously spread into the whole sector but directed in beams. The antenna gain is proportional to the number of antenna elements in the antenna array and may be in the main direction about 20 dB. In the other directions, side lobe levels may be from -10 to -40 dB compared to the main beam. Through the use of directed beams, interference levels in the network are reduced and thereby the capacity is increased. It is known that antenna arrays can be used to create directed beams. These antenna arrays are two-dimensional antenna arrays which are fed by amplitude and/or phase angle weighted signals. By adjusting the signals being applied to each of the antenna elements, the direction of a beam can be controlled. Adaptive antennae using fixed beams as well as adaptive beams are known. Adaptive beams are directed towards a dedicated mobile station and move according to the movement of the mobile station. Fixed beams have a dedicated direction and mobile stations being allocated in the sector of a directed beam use the available channels of this beam. In case the mobile station moves through a sector and leaves the sector of coverage of one beam, handover procedures ascertain that the mobile station uses the available channels of the next beam.

The problem of both approaches is that some common channels, like the common pilot channel (CPICH) in the wide band code division multiple access (WCDMA) system or the broadcast channel (BCCH) in the global system for mobile communication (GSM) have to be delivered to the entire sector at all times. It is understood, that this problem of dedicated channels and broadcast channels is present in any communication system which deploys common

as well as dedicated information to specific users. When using directed beams, notches with low signal strength appear in a cell. In case the fixed beam approach is used, these notches can be made quite small and thus the reception of the common channels is improved. However, this would require that all common channels have to be exactly in the same phase at each antenna element of the antenna array. That would require that feeder cables and other elements of the base station have to be calibrated.

To overcome this problem, a known approach is to transmit a control channel simultaneously over the entire cell or cell sector region. To satisfy this requirement, a separate sector antenna has to be used. As the size of a base station antenna is crucial, any additional antenna element has to be avoided.

According to these problems, it is the objective of the invention to provide a base station with an antenna array being capable of sending directed beams as well as undirected beams, whereby the size of the base station is kept small.

According to the invention this objective is met by a base station wherein said antenna array comprises at least two groups of antenna elements, each group comprising at least two antenna elements, where one first group of antenna elements transmits at least one undirected beam, bearing at least one of said broadcast channel that is common for said whole sector, into said whole sector, and where one second group of antenna elements transmits at least two directed beams, each beam bearing said dedicated channels that are intended only for a part of said sector and each beam covering said part of said sector, respectively. Thus the antenna array

can be kept small, as all antenna elements can be arranged within one antenna radome. The manufacturing of such an antenna array is easy, as all antenna elements are the same. There is no demand for two different types of antenna elements. It is understood that the sector of interest may be in the azimuth plane as well as the vertical plane.

In case said antenna elements of said first group of antenna elements are located at the outermost part of said antenna array and said antenna elements of said second group of antenna elements are located at the inner part of said antenna array, the antenna array can be kept small and the mutual coupling between the antenna elements is equal. In some known antenna arrays, the outermost antenna elements are dummy elements, which provide an equal mutual coupling characteristic among the antenna columns which are used for fixed beams. According to the invention, these dummy elements are used to transmit the broadcast channel. Such, the broadcast channel can be applied to the whole sector and the size of the antenna can be kept small. It is understood that a single directed beam is not limited only to its proposed direction. As can be seen in Fig. 1 the radiation power of a single beam is distributed in the azimuth plane. The antenna gain is being adapted in a way, that the gain in the main direction is about 10 to 20 dB. In the direction of the adjacent beam, the gain of the first beam is in the order of 0 to -20 dB. Thus spatial filtering is achieved so that adjacent beams have low interference.

The base station can be part of a wide band code division multiple access (WCDMA) network, a time division multiple access (TDMA) network, or a global system for mobile communication (GSM) network. Said signals being

transmitted by said base station comply with the respective standard.

The beamforming means can be passive, where the directions of the directed beams are fixed. Such a passive beamforming means is a butler matrix. The advantage of the passive beamforming means is that the antenna elements do not require phase coherence between the transceiver and the beamformer. That allows the feeder cables to have arbitrary phases. The butler matrix weights the phase angle and/or the amplitudes of the signals being fed to the antenna array in a way that the direction of the directed beams are fixed but cover the whole sector of coverage of the antenna array. The use of a butler matrix minimises beamforming loss and generates orthogonal beams.

In case the beamforming means is a digital beamformer, the beams are fully steerable. The digital beamformer is able to weight phase angle and/or amplitude of the transmitted signals in a way, that the direction of the beam is adapted to transmission needs. This is for example that the beam moves along with a mobile station through the whole sector of coverage of the antenna array. The number of downlink beams can be increased by that approach. In such an approach, the direction of arrival of the uplink signals at the antenna array has to be estimated by the beamforming means to direct the beam to the respective mobile station and to move the beam according to the movement of the mobile station.

The overall antenna gain can be increased by increasing the number of antennae elements in said antenna array. Additional antennae can be vertically arranged in columns where up to 20 or more antennae can be in one column.

The sector of interest can be in the vertical plane. In that case, each row of antennae may be fed with signals being phase angle and/or amplitude adjusted in a way that the beam is also formed in the vertical plane.

By using micro strip patches as antennae, the size of said antenna array can be minimised. To ensure adequately small correlation between the corresponding beams in all environments, the sector antennae, which are the outermost dummy elements, can be arranged in a way that they have orthogonal polarisation. This would be for example +45°/ - 45° or horizontal/vertical polarisation.

Inter-element spacing of half a wavelength between antenna elements allow beamsteering between -90°/+90° without grating lobes. These grating lobes are multiple main beams. They appear in case inter-element spacing is greater than one wavelength of a carrier frequency. The reason is the spatial Nyquist sampling criteria.

By using an uniform linear array, the antenna elements are equally spaced a part.

The number of useable beams within one sector can be increased, if the antenna elements transmit dual polarised signals. In this approach, any antenna element of the antenna array transmits dual polarised signals. Thus the number of beams is doubled.

In another embodiment of the invention, at least two antenna arrays are arranged on a perimeter. By arranging said at least two antenna arrays on a perimeter, for instance in an triangular shape, a complete cell can be covered. In the embodiment of Fig. 5 , each antenna array covers a cell sector of 120°. With four antenna elements

per sector, two directed beams and one undirected beam cover each cell sector. In cases the signals are not dual polarised, the received signals of all antennae, including the dummy antennae, can be combined to generate a complete receive signal.

To increase the signals strength, signals bearing broadcast channels are being amplified with separated amplifiers, which can be low power amplifiers and signals bearing dedicated channels are being amplified with power amplifiers, in particular wide band power amplifiers. As the antenna gain is increased in the direction of the beams, the power requirement of said power amplifiers is reduced.

Also said received signals can be amplified with low noise amplifiers, which increases the reception quality. Low noise amplifier as well as power amplifier can be integrated in said butler matrix as well as in said antenna elements. In such a case, the feeder cables can be sized smaller, which means that these cables are lighter and cheaper.

In the following, possible embodiments of the invention are depicted in the drawing in which:

Fig. 1 shows the beam radiation pattern of one beam;

Fig. 2 shows an antenna array arrangement;

Fig. 3 shows one antenna element with micro strip patches;

Fig. 4 shows the radiation pattern of an antenna array;

Fig. 5 shows a cell with six directed and three sector beams.

In Fig. 2 one possible embodiment of an antenna array is shown. Four antenna elements 200, 202, 204 and 206 are arranged in columns besides each other. The antenna elements are spaced in the order of half a wavelength apart. The outermost antenna elements 200 and 202 are fed by a transceiver unit 210 with a broadcast channel. The broadcast channel transmits signals being valid for a whole sector. This is for example a common pilot channel (CPICH) in wide band code division multiple access networks. These antenna elements 200, 202 transmit the broadcast channel in the whole sector. The inner antenna elements 204, 206 are connected to the transceiver unit 210 via the butler matrix 208. The signals generated by the transceiver unit 210 are phase shifted by the butler matrix 208 in a way that the antenna elements 204 and 206 transmit directed beams bearing dedicated channels. The direction of the transmitted beams is chosen in a way that the whole sector is covered by a combination of the directed beams. Said butler matrix 208 is connected to a low noise amplifier/wide band power amplifier 214,212 which includes also duplexers to separate a transmit Tx branch and a receive Rx branch. Said low noise amplifier/wide band power amplifier 214,212 might also be integrated into the Butler matrix 208.

In Fig. 3 one antenna element 202 of array 200, 202, 204, and 206 is shown. This antenna element 202 comprises micro strip patches 300, 302, and 304. The micro strip patches 300-304 are arranged in a way that the polarisation of the transmitted signals is horizontal/vertical. Instead of horizontal/vertical

polarising patches, also cross polarising (+45°/-45°) patch elements can be used. Thus dual polarised elements or single polarised elements can be applied.

In Fig. 4 a coverage sector of an antenna array 400 is shown. The broadcast channel is transmitted in a way that the signal can be received with a sufficient signal level in the area 402. The dedicated channels are divided into four directed beams 404, 406, 408 and 410. The directed beams cover in combination the whole sector of coverage.

In Fig. 5 a base station is shown, where three antenna arrays are arranged on a perimeter in a triangle 500. With such an arrangement, a whole cell can be covered with broadcast and dedicated channels. Each antenna element of the triangle 500 transmits a broadcast channel into the sector 501a, 501b, 501c. In each sector two dedicated channels are transmitted in beams 502a, 502b, 502c and 504a, 504b, 504c. The interference ratio of adjacent cells is thus decreased and the available bandwidth can be used more efficiently.

Having described preferred embodiments of a novel hybrid antenna array (which are intended to be illustrative and not limiting), it is noted that modifications and variations can be made by persons skilled in the art in light of the above teachings.

Claims

1. Base station in a mobile communication network, in particular a cellular mobile communication network comprising

- at least one antenna array with at least four, parallel arranged antenna elements (200, 202, 204, 206), sending signals bearing dedicated as well as broadcast channels into a sector of interest,
- beamforming means (208) adjusting phase angle and/or amplitude of at least one of said signals being applied to the antenna elements,
- and a transceiver unit (210) generating and receiving said signals,
- **characterised in that**
- said antenna array (200, 202, 204, 206) comprises at least two groups of antenna elements, each group comprising at least two of said antenna elements,
- where one first group of antenna elements (200, 202) transmits at least one undirected beam (402), bearing at least one of said broadcast channel that is common for said whole sector, into said whole sector, and
- where one second group of antenna elements (204, 206) transmits at least two directed beams (404-410), each beam bearing said dedicated channels that are intended only for a part of said sector and each beam covering said part of said sector respectively.

2. Base station according to claim 1,
characterised in that
said antenna elements of said first group of antenna elements (200, 202) is located at the outermost part of said antenna array and that said antenna elements of said second group of antenna elements (204, 206) are located at the inner part of said antenna array.

3. Base station according to claim 1 to 2,
characterised in that
said signal transmitted by said antenna array is a wide band code division multiple access (WCDMA) signal.

4. Base station according to claim 1 to 2,
characterised in that
said signal transmitted by said antenna array is a time division multiple access (TDMA) signal.

5. Base station according to claims 1 to 4,
characterised in that
said beamforming means (208) is a butler matrix by which said signals bearing dedicated channels are phase angle and/or amplitude weighted in a way that said directions of said directed beams are fixed.

6. Base station according to claims 1 to 4,
characterised in that
the beamforming means (208) is a digital beamformer by which said signals bearing dedicated channels are phase angle and/or amplitude weighted in a way that said directions of said directed beams are adapted according to transmission needs.

7. Base station according to claims 1 to 6,
characterised in that
said antenna elements (200, 202, 204, 206) are vertically arranged in columns.

8. Base station according to claim 1 to 7,
characterised in that
said antenna elements (200, 202, 204, 206) comprise a plurality of antennae (300, 302, 304).

9. Base station according to claim 8,
characterised in that
said plurality of antennae are micro strip patches (300, 302, 304).

10. Base station according to claims 1 to 9,
characterised in that
said antenna elements form a uniform linear array.

11. Base station according to claim 1 to 10,
characterised in that
the inter-element spacing between said antenna elements is less that half a wavelength of a carrier frequency.

12. Base station according to claims 1 to 11,
characterised in that
said first group of antenna elements transmits orthogonal polarised signals.

13. Base station according to claims 1 to 12,
characterised in that
said antenna elements of said first group and said second group transmit dual polarised signals.

14. Base station according to claims 1 to 13,
characterised in that
at least two antenna arrays are arranged on a perimeter, each of said antenna arrays transmitting into a different direction, whereby said signals transmitted by said at least two antenna arrays cover a whole cell of 360° in the azimuth plane.

15. Base station according to claims 1 to 14,
characterised in that
said transceiver unit combines received signals of all antenna elements.

16. Base station according to claims 1 to 15,
characterised in that
said received signals are amplified with low noise amplifiers (212, 214).

17. Base station according to claims 1 to 16,
characterised in that
said signals bearing said broadcast channels are amplified with dedicated amplifying means and that said signals bearing said dedicated channels are amplified with power amplifiers (212, 214).

18. Base station according to claims 16 or 17,
characterised in that
said butler matrix (208) comprises said power amplifiers and said low noise amplifiers (212, 214).

19. Base station according to claims 16 or 17,
characterised in that
said antenna elements (204, 206) comprise said power amplifiers and said low noise amplifiers (212, 214).

20. Method for operating a base station in a mobile communication network, in particular a cellular mobile communication network in which signals bearing dedicated as well as broadcast channels into a sector of interest are sent by at least one antenna array with at least four, parallel arranged antenna elements (200, 202, 204, 206), the phase angle and/or amplitude of at least one of said signals being applied to the antenna elements are adjusted by beamforming means (208) and said signals are generated and received by a transceiver unit (210), **characterised in that,**
one first group of antenna elements (200,202) transmits at least one undirected beam (402), bearing at least one of said broadcast channel that is common for said whole sector, into said whole sector, and one second group of antenna elements (204,206) transmits at least two directed beams (404-410), each beam bearing said dedicated channels that are intended only for a part of said sector and each beam covering said part of said sector respectively, whereby said antenna array (200, 202, 204, 206) comprises at least two groups of antenna elements, each group comprising at least two of said antenna elements.

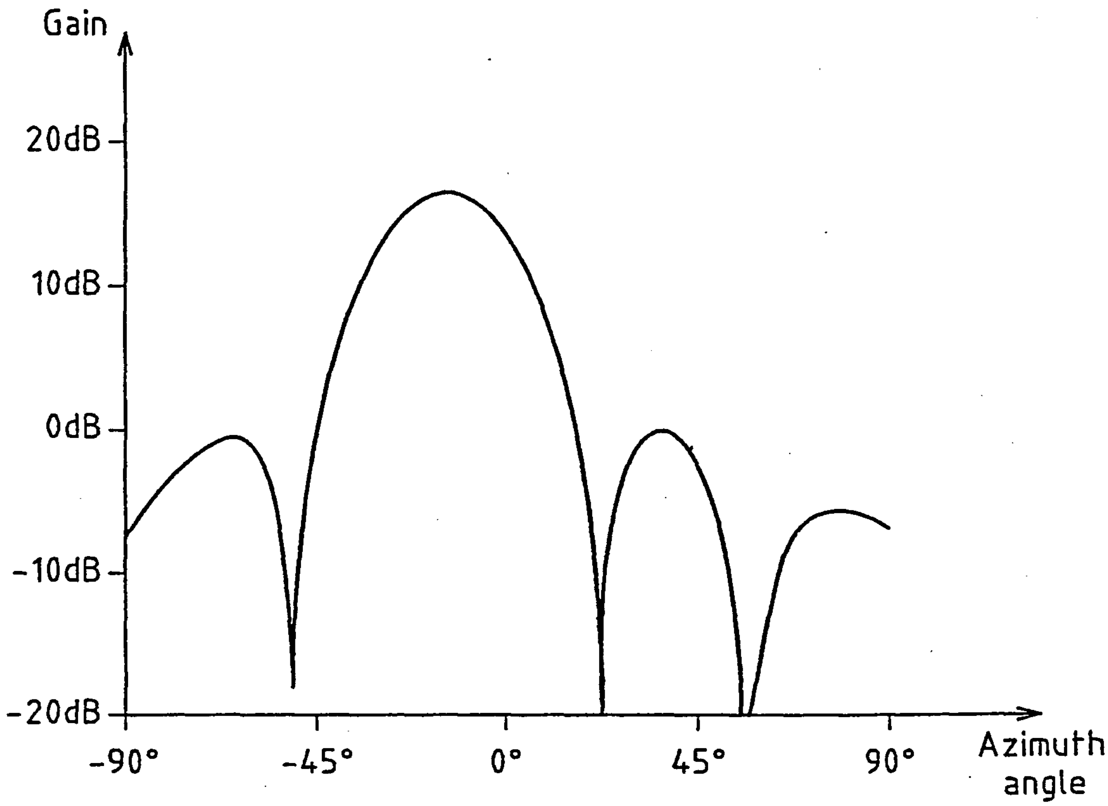
Gain
20dB
10dB
0dB
-10dB
-20dB
-90°
-45°
0°
45°
90°
Azimuth angle

Fig.1

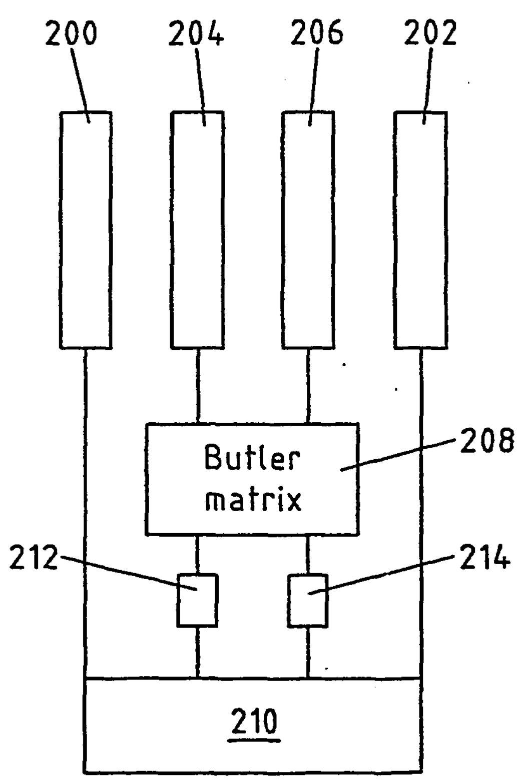
200
204
206
202
Butler matrix
208
212
214
210

Fig.2

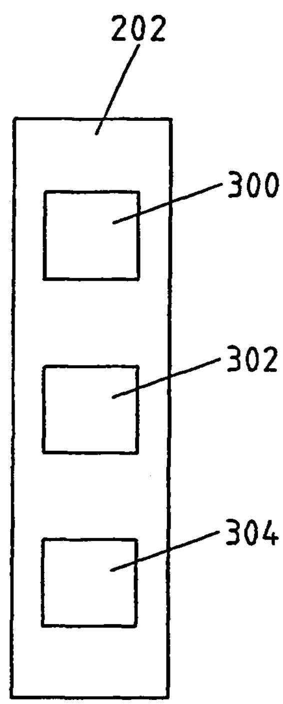

Fig.3

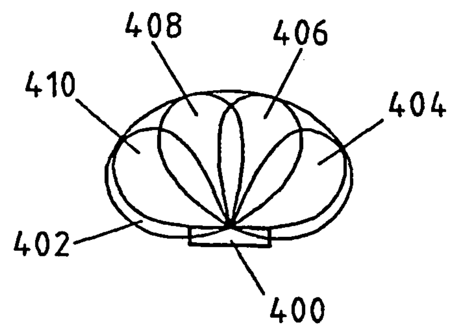

Fig.4

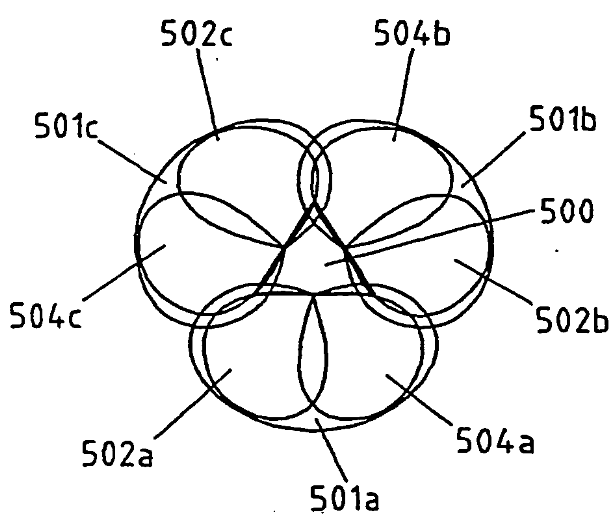

Fig.5

INTERNATIONAL SEARCH REPORT

Inten al Application No
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A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H01Q1/24 H01Q25/00 H01Q3/40

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H01Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 98 50981 A (ERICSSON TELEFON AB L M) 12 November 1998 (1998-11-12)	1-5,7,8, 10, 15-17,20
A	page 1, line 9 - line 26 page 2, line 5 - line 28 page 4, line 6 - line 29 page 5, line 1 - line 11 page 8, line 8 - line 13 page 9, line 14 - line 18 page 13, line 4 - line 10; claims 1,7,11; figures 1-7 ---	14
Y	US 4 638 318 A (GUTLEBER FRANK S) 20 January 1987 (1987-01-20) column 1, line 52 - line 68 column 2, line 41 - line 50; claim 1; figures 1,2 ---	1-5,7,8, 10, 15-17,20

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"P" document published prior to the international filing date but later than the priority date claimed

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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Date of the actual completion of the international search	Date of mailing of the international search report
11 January 2001	19/01/2001

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Moumen, A

INTERNATIONAL SEARCH REPORT

Inten ial Application No
PCT/EP 00/04496

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	WO 95 34102 A (ERICSSON TELEFON AB L M ;FORSSEN ULF GOERAN (SE); BERG JAN ERIK (S) 14 December 1995 (1995-12-14) page 4, paragraph 2 page 5, line 4 - line 29 page 6, line 1 - line 4 page 6, line 18 - line 27; claims 1-30; figures 1-6	6-13,16, 19
A	TAROMARU M ET AL: "DOWNLINK CONTROL CHANNEL TRANSMISSION WITH ANTENNA DIRECTIVITY SWITCHING OR SPACE DIVERSITY AT BASE STATIONS" ELECTRONICS & COMMUNICATIONS IN JAPAN, PART I - COMMUNICATIONS,US,SCRIPTA TECHNICA. NEW YORK, vol. 81, no. 12, 1 December 1998 (1998-12-01), pages 45-54, XP000782782 ISSN: 8756-6621 page 47, left-hand column, paragraph 4	11
A	US 5 861 844 A (LARAMIE DANIEL ET AL) 19 January 1999 (1999-01-19) the whole document	14
A	EP 0 831 551 A (HONDA MOTOR CO LTD) 25 March 1998 (1998-03-25) figure 1	19

INTERNATIONAL SEARCH REPORT

ormation on patent family members

Intern ial Application No
PCT/EP 00/04496

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 9850981 A	12-11-1998	SE 509278 C	11-01-1999
		AU 7461798 A	27-11-1998
		CN 1261989 T	02-08-2000
		EP 0981839 A	01-03-2000
		SE 9701722 A	08-11-1998
US 4638318 A	20-01-1987	CA 1211836 A	23-09-1986
WO 9534102 A	14-12-1995	AU 686388 B	05-02-1998
		AU 2583595 A	04-01-1996
		CA 2191956 A	14-12-1995
		CN 1150498 A	21-05-1997
		EP 0763264 A	19-03-1997
		FI 964562 A	14-11-1996
		JP 10501661 T	10-02-1998
US 5861844 A	19-01-1999	AU 700158 B	24-12-1998
		AU 4248096 A	19-06-1996
		BR 9509928 A	30-09-1997
		CA 2206101 A	06-06-1996
		CN 1173266 A	11-02-1998
		EP 0806121 A	12-11-1997
		JP 3014767 B	28-02-2000
		JP 11503577 T	26-03-1999
		RU 2142181 C	27-11-1999
		WO 9617487 A	06-06-1996
EP 0831551 A	25-03-1998	JP 10093321 A	10-04-1998
		US 6034641 A	07-03-2000

Form PCT/ISA/210 (patent family annex) (July 1992)